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ARTIFICIAL SOLAR ECLIPSE EXPERIMENT DURING THE JOINT
FLIGHT OF THE SOYUZ AND APOLLO SPACECRAFT

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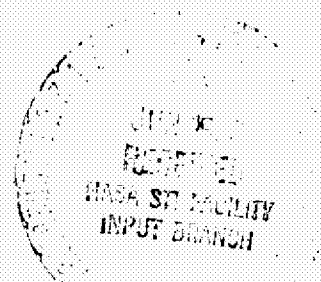
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16. Abstract A short description is given in a popular form of an artificial solar eclipse, performed for the first time in space during the joint flight of the Soviet and American spacecraft. Data is presented on observations of the solar eclipses and their role in the study of the upper layers of the solar atmosphere--the corona. The physical nature of the solar corona is briefly described.			
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ARTIFICIAL SOLAR ECLIPSE EXPERIMENT DURING THE JOINT FLIGHT OF THE SOYUZ AND APOLLO SPACECRAFT

G. M. Nikol'skiy

I. Solar Eclipses

The most ancient observations of solar eclipses were performed, /*3 apparently, approximately 5000 years ago in India, and then in China. We have evidence of the fact that approximately 3000 years ago eclipse tables were compiled in Babylon. Scientific investigations of solar eclipses and their prediction began in ancient Greece in the VI century B.C., and in the II century B.C., the great Greek astronomer Hipparchus, already knowing the specifics of the moon's movements, could rather well predict the time and place of a solar eclipse.

The angular dimensions of the sun and the moon are identical to an observer on the earth. When the angular dimensions of the moon are somewhat greater than the dimensions of the sun, and the moon falls into the line "observer-sun", a total solar eclipse occurs. It is observed on the earth in a belt approximately 200 kilometers wide and extends for several thousand kilometers. The duration of a total eclipse for a motionless observer is from several seconds to 7 minutes or more. All numbers depend on the eclipse and the position of the observer within the belt of the total phase. On the average one total eclipse occurs during 1.5 years. From the twentieth century the overall duration of total eclipses was approximately four hours.

* Numbers in the margin indicate pagination in the foreign text.

II. The Solar Corona

During total solar eclipses, when the brightness of the sky /4 decreases by thousands of times and the bright source of light--the sun is covered by the moon--a corona is visible which is a radiant halo around the lunar disk, extending for considerable distances which exceed the dimensions of the sun. The brightness of the corona is millions of times less than the brightness of the sun and drops with distance from the latter. The material of the corona is a hydrogen plasma--gas in the state of almost total ionization (i.e., the electron and the proton, which a hydrogen atom consists of, lose their connection with each other). The temperature of the corona, determined by the velocity of particle movements, reaches a million degrees, and in some regions even tens of millions of degrees. The shape of the corona is determined by the magnetic fields of the sun and change rather quickly (essentially during several days). The corona changes into interplanetary gas, i.e. it actually does not have boundaries. The movement of the material in the corona is basically directed outwards, and as one is accustomed to say, there exists a "solar wind", i.e. the discharge of plasma with magnetic fields.

Study of the solar corona is extremely important in scientific and applied respects. The stable electromagnetic radiation (ultra-violet and X-ray), and the corpuscular radiation ("solar wind"), originating in the corona, reach the earth and affect the upper layers of its atmosphere.

III. Artificial Solar Eclipses

In spite of numerous attempts of scientists, it was only in 1930 that the Frenchman, B. Lyot, succeeded in constructing a special telescope-coronagraph, by which it is possible to observe the most /5 internal and bright regions of the corona from those places on the

earth where the brightness of the sun is small (high in the mountains).

The largest coronagraph in the world (the construction was developed in the Institute of Earth Magnetism Radiowaves Propagation by the author jointly with A. A. Sazanov) was constructed in 1967 and was installed at the Gornaya Astronomical Station, USSR Academy of Sciences, not far from Kislovodsk (at an elevation of 2100 meters).

In Lyot's type of coronagraph, the disk eclipsing the sun ("the artificial moon") is inside the telescope, after the main lens. The idea of installing an additional external disk, throwing the shadow back on the lens, also is Lyot's and was accomplished practically for the first time by the Americans Newkirk and Bolin. This coronagraph with an "external eclipse" was used by the Americans for observations on board the space lab Skylab and by the French on balloons. By necessity, the small dimensions of the instrument and obligatory use of neochromatic optics decrease the effectiveness of the observations, making it impossible to obtain the most external corona.

If the earth's atmosphere, dispersing the solar light, were absent, the solar corona could be observed each time at sunrise and sunset. Such conditions exist on the moon. The American Apollo astronauts in a circumlunar orbit observed the flow of the corona and the interplanetary medium. The commander of Apollo-17, E. Cernan, performed successful observations.

V. Artificial Eclipse in Space

The property of light to bend obstacles, penetrating into the area of the geometrical shadow--diffraction--is one of the basic barriers for observing the corona. Why does diffraction not

interfere when making observations during total solar eclipses? It is because of the great distance of the screen--the moon from the observer. Light, deflected into the area of the shadow, with /6 great distances to the observer, is dispersed to a greater area, and its intensity becomes small.

These considerations and the small brightness of the sky in space led the author and his colleague from the Institute of Space Research, USSR Academy of Sciences, A. I. Simonov, to the idea of creating an artificial solar eclipse during the joint flight of the Soviet and American spacecraft in the summer of 1975. The spacecraft Apollo, having a round cross-section, will play the role of the moon, the eclipse will be photographed on board Soyuz. A decisive role in this experiment is played by the precise calculation of the movement of the ships and coordination in the activities of the crews who are performing the maneuvers. The spacecraft Soyuz was launched from the Baykonur cosmodrome on July 15, 1975, at 1520 hours Moscow time. The launch of the American ship Apollo takes place in 7.5 hours from the Kennedy Space Center. After two days of flight along heliocentric orbits (altitude approximately 200 kilometers, inclination to the earth's equator 52° , period of revolution 1.5 hours) the ships perform the first docking on July 17, at 1900 hours (Moscow time). After 44 hours of flight of the docked ships, on July 19, the undocking begins and the "artificial solar eclipse" experiment commences. The next sunrise on the 65th orbit of Soyuz will occur on July 19, at 1500 hours. The docked ships will meet the sunrise in a position oriented toward the sun: the nozzle of the propulsion engine of Apollo is directed towards the sun. Within 1 minute and 15 seconds after the sunrise the ships will begin their separation along a direction toward the sun under the action of the spring pushers in the docking system.

In half a minute, during which Apollo increases the separation /7 velocity and turns on the control system engines, the ships will begin to separate by inertia at a velocity of 1 meter per second.

At this moment the observations of the eclipse will begin. A camera, loaded with a wide (70 mm) highly sensitive photographic film, is installed on Soyuz close to the front window. The frame covers a field of 30 by 30 degrees. Exposures are made automatically, alternating cyclically by groups of four (from 0.1 second to 10 seconds). The angular dimensions of Apollo are great at the beginning of the experiment: almost the entire camera field of vision is covered. With an increase in distance between the ships from each, more internal objects of the solar corona will be discovered. In 3.5 minutes the angular dimensions of Apollo will exceed the angular diameter of the sun by only 2 times, while the distance between the ships reaches more than 200 meters. Then Apollo begins maneuvers for returning closer to Soyuz, in order to make a second docking. By this time the "eclipse" experiment is finished, i.e. the ships will depart from a line directed toward the sun. The second docking will take place 40 minutes after the beginning of the experiment, and 10 minutes later the sun will set.

It is quite important that the experiment is performed immediately after sunrise, i.e. where the sun is high above the horizon. The illuminated portion of the earth, seen from the spaceship, is great, and the radiation proceeding from it will light up the window of Soyuz. Dispersion of light in the mirror will hinder the observations. With a small solar elevation above the horizon, this illumination is substantially lower. But in order to avoid this "parasite" background, a special shield was installed in front of the Soyuz window, which eliminated the illumination from the earth and the bright belt of the terrestrial atmosphere along the horizon.

The shield and the camera had already been tested under space conditions during the flight of Soyuz-16. Testing showed that the equipment is completely suitable for conducting the experiment. /8

During the experiment the crew of the American ship will photograph Soyuz. These materials will make it possible to determine the conditions of shading during post-flight analysis of the results. Processing of all materials, obtained during the artificial eclipse, will be jointly carried out by American and Soviet scientists.

In addition to the "eclipse" experiment, attempts will be made in this flight on board Soyuz to find the corona rays in the night sky (with a small sinking of the sun below the horizon). Moreover, while conducting the experiment, the scientists of the Institute of Earth Magnetism and Ionosphere will conduct synchronous observations of the sun from Mt. Elbrus using a portable special coronagraph, specially manufactured for this purpose. This will make it possible to establish the physical connection between the internal and external corona.

"The artificial solar eclipse" will give researchers valuable methodical material. Before the performance of this experiment it is difficult to state anything definite about the light "background" from the terrestrial radiation and diffraction from the solar light on Apollo. After necessary data is obtained, possibilities will be opened for performing artificial eclipses in space with even greater scientific efficiency.

In addition to observing the corona, the "eclipse" experiment will have the task of photographing the "atmosphere" around the spaceship Apollo, which will be formed due to the discharge of gases absorbed by the surface of the ship and the operation of the engines. These investigations also have important scientific and applied significance.